

Robotics Technology

From Space Exploration to Autonomous Vehicles



Dr. Terry Fong

Chief Roboticist
NASA Ames Research Center
terry.fong@nasa.gov

NASA and Autonomous Vehicles



NASA Missions

Planned human-machine interaction

Natural and time delayed environments

Aerial, space, and planetary navigation

On-board and ground control autonomy

Cyber-security for “one-off” systems

...

Common Technologies

Autonomy

Advanced Planning & Scheduling Algorithms, etc.

Human-Autonomy Teaming

Robotic Supervision including Human/Robotic Interactions, etc.

Networked Operations

Remote Vehicle Management, etc.

Prognostics / Diagnostics

Including State Management, etc.

Sensors and Perception

Data Processing / Fusion Methodologies, etc.

Verification and Validation

Methodologies & Application Experiences, etc.



Autonomous Vehicles

Diverse human-machine interaction

Structured environment

GPS & map-based navigation

Distributed and cloud-based autonomy

Cyber-security for consumer product

...



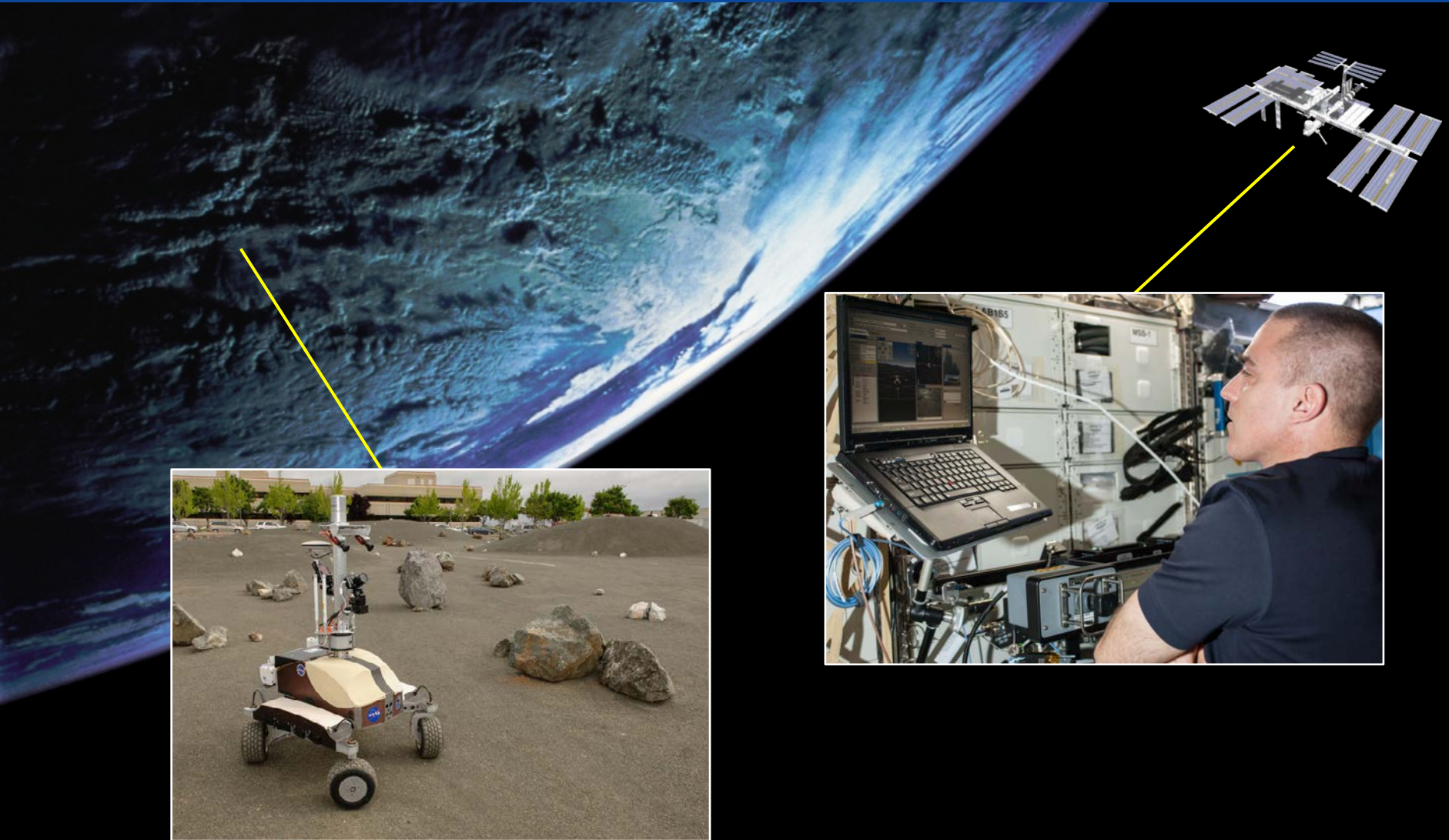
Imperfect space robots

Anomalies, corner cases, and edge cases

- The real world is highly uncertain and changing
- Many situations require unique autonomy solutions to be developed, but these are often too costly to develop, test, and validate
- “There are **known knowns**. There are things we know that we know. There are **known unknowns**. That is to say, there are things that we now know we don't know. But there are also **unknown unknowns**. There are things we do not know we don't know.” – *Donald Rumsfeld (2/12/2002)*



NASA teleoperation of space robots



Space Station tech demo (2013)



Astronaut-robot teaming



Imperfect autonomous vehicles

Anomalies, corner cases, and edge cases

- When a construction worker uses hand gestures to provide guidance, or direction, no autonomous car today can reliably make the right decision.
- When the sun is immediately behind a traffic light, most cameras will not be able to recognize the color of the signal through the glare.
- If we see children distracted by the ice cream truck across the street, we know to slow down, as they may dash toward it.

– Andrew Ng (*Wired*, 3/15/2016)



Nissan teleoperation of AVs



**Mobility managers at
a support center**



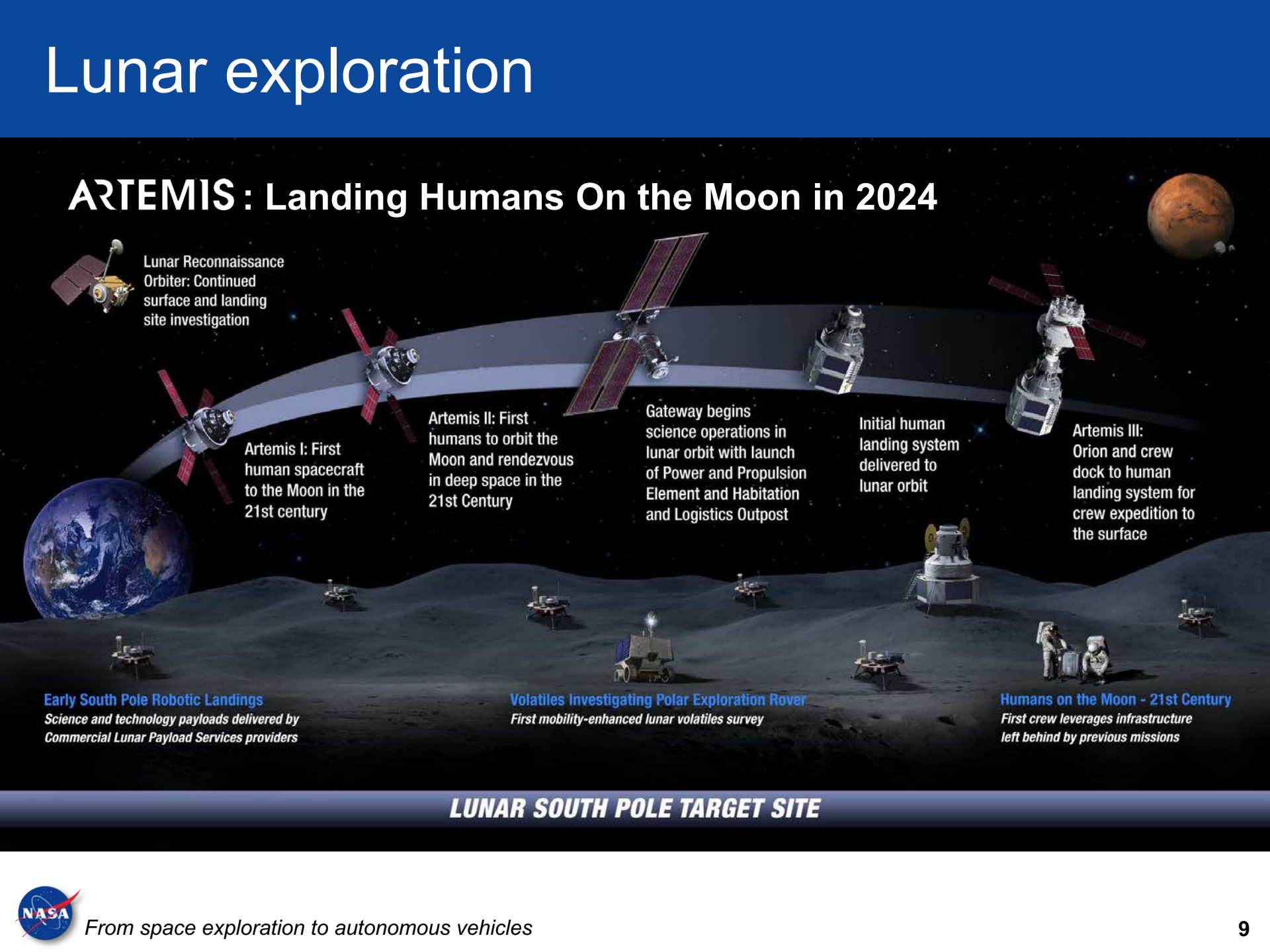
Consumer Electronics Show (2017)



From space exploration to autonomous vehicles

Lunar exploration

ARTEMIS: Landing Humans On the Moon in 2024



The diagram illustrates the Artemis lunar exploration mission timeline and the target site at the Lunar South Pole. A curved path represents the mission sequence, starting from Earth on the left and moving towards the Moon on the right. Various spacecraft and rovers are shown along this path and on the lunar surface. The Earth is visible on the left, and the Moon's surface is depicted at the bottom. The Mars is visible in the upper right corner. The mission sequence includes: Lunar Reconnaissance Orbiter (continued surface and landing site investigation), Artemis I (first human spacecraft to the Moon in the 21st century), Artemis II (first humans to orbit the Moon and rendezvous in deep space in the 21st century), Gateway (begins science operations in lunar orbit with launch of Power and Propulsion Element and Habitation and Logistics Outpost), Initial human landing system delivered to lunar orbit, and Artemis III (Orion and crew dock to human landing system for crew expedition to the surface). On the lunar surface, there are several rovers and landers, including the Volatiles Investigating Polar Exploration Rover (first mobility-enhanced lunar volatiles survey) and the Humans on the Moon (first crew leverages infrastructure left behind by previous missions). The target site is labeled 'LUNAR SOUTH POLE TARGET SITE'.

Lunar Reconnaissance Orbiter: Continued surface and landing site investigation

Artemis I: First human spacecraft to the Moon in the 21st century

Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st Century

Gateway begins science operations in lunar orbit with launch of Power and Propulsion Element and Habitation and Logistics Outpost

Initial human landing system delivered to lunar orbit

Artemis III: Orion and crew dock to human landing system for crew expedition to the surface

Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers

Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey

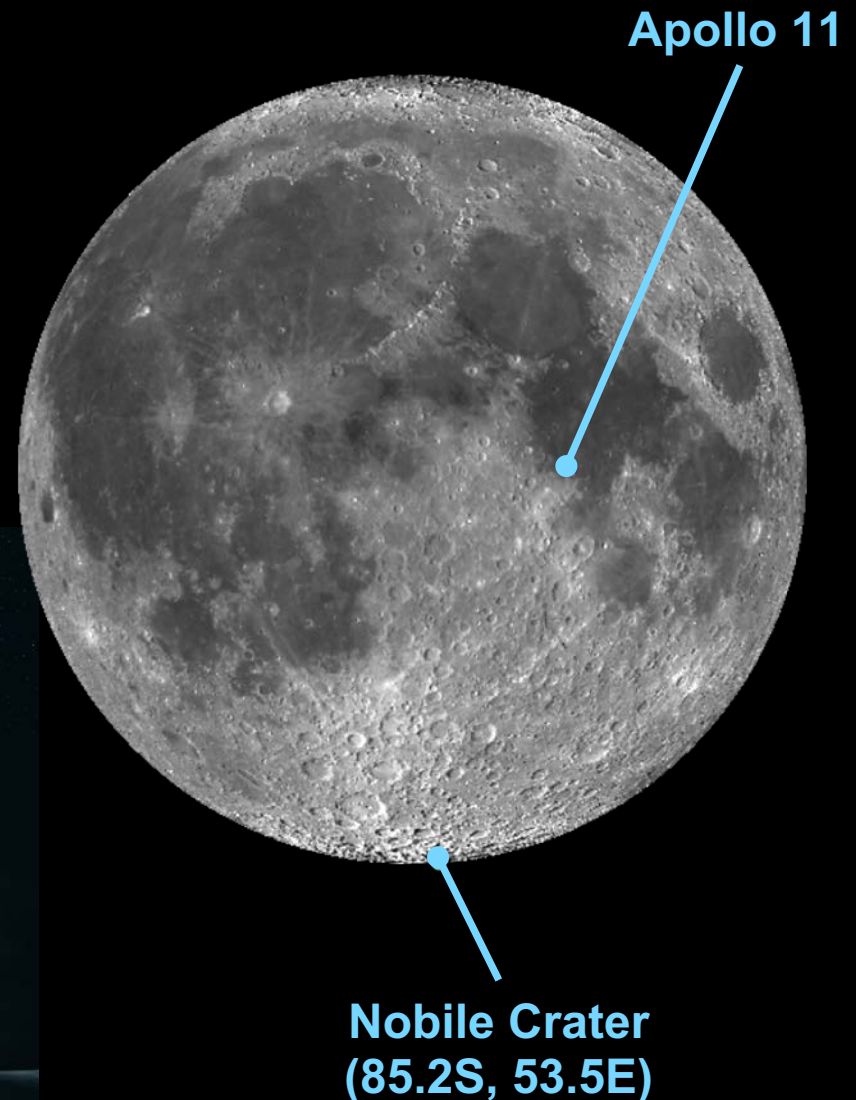
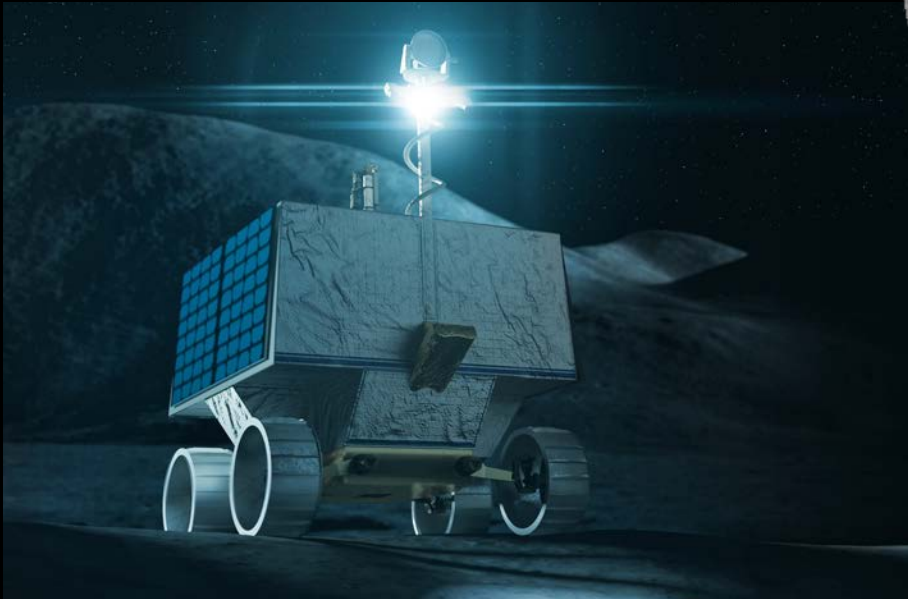
Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions

LUNAR SOUTH POLE TARGET SITE

NASA VIPER (2023)

Lunar rover mission

- Launch in November 2023
- Search for buried water ice in permanently shadowed regions
- All electric, golf-cart sized rover (450W peak, 490 kg)
- 20+ km over 120 days using direct comm + teleop

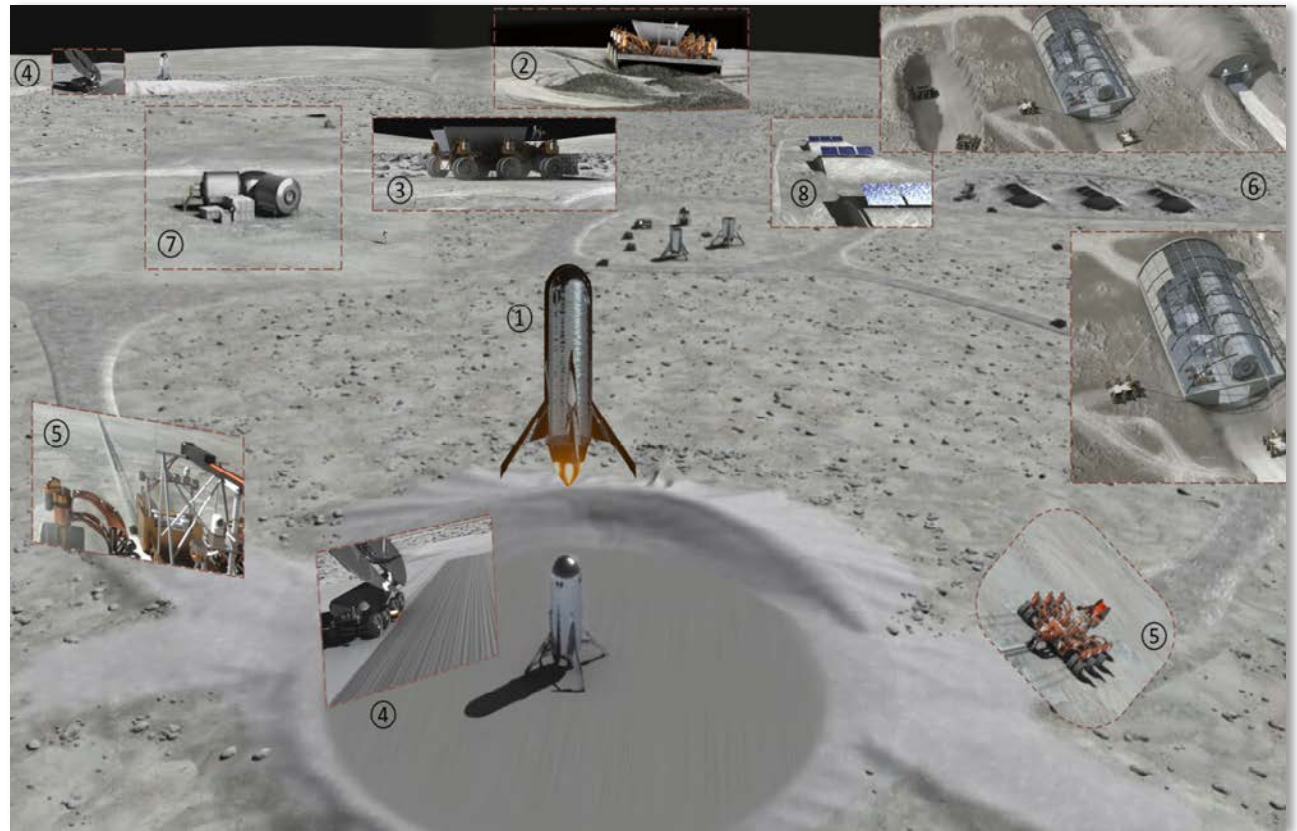




Lunar surface robotics (2025 - 2035)

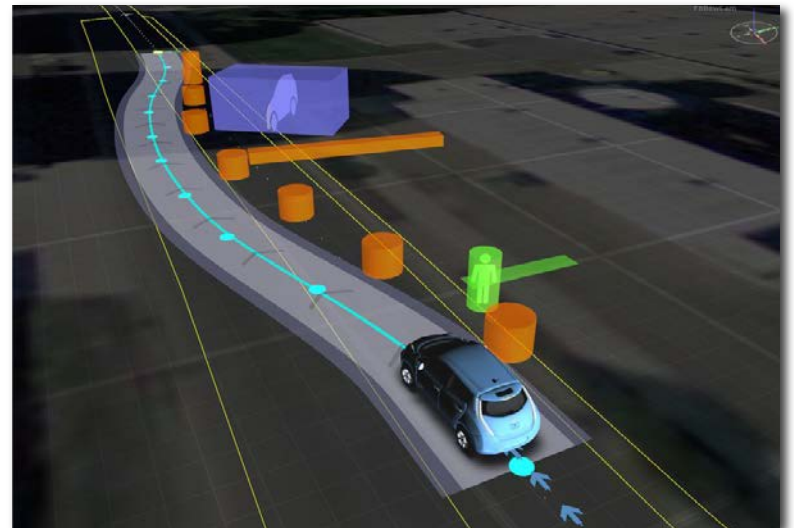
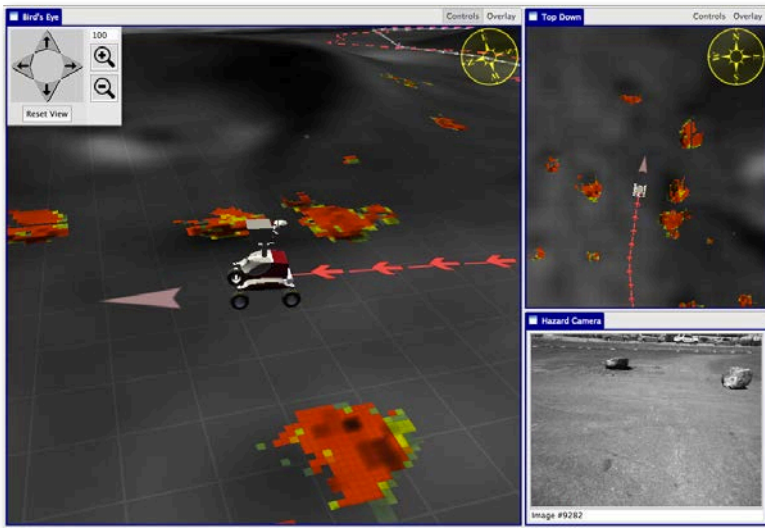
Autonomous surface construction, excavation, and outfitting

- ① supplies are landed
- ② excavation
- ③ material transport
- ④ landing pad building
- ⑤ cable layout
- ⑥ structure outrigging
- ⑦ fuel depot setup
- ⑧ power plant and grid setup



A shared world model is needed to ensure effective and safe operations of multiple systems ...

Questions?



From space exploration to autonomous vehicles